AFRL-SR-BL-TR-98-

0858

REPORT DOCUMENTATION PAGE

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AN…
	December 1998	Final Technical 9/30/94 through …

4. TITLE AND SUBTITLE
A Foveated Imaging System to Reduce Transmission Bandwidth of Video Images from Remote Camera Systems

5. FUNDING NUMBERS
contract
F49620-96-C-0053
STTR/TS
65502F

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7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

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8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)

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10. SPONSORING / MONITORING AGENCY REPORT NUMBER

19990115 032

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION / AVAILABILITY STATEMENT
Report may be freely distributed.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 Words)*
This is the final progress report for a joint project between Geisler's laboratory at the University of Texas at Austin and OWL Displays Inc., to develop a real time variable resolution (foveated) imaging system for video communications tasks such as remote control of unmanned vehicles. Although the OWL side of the project might best be described as a modest success, we believe the software and software/hardware integration performed at UT has been a big success. A general purpose real-time linkable library (for Pentium class computers running the Windows95/98/NT OS) has been developed for coding and decoding variable resolution static images and video, both in 8-bit gray scale and 24-bit color. Real-time demonstration executables using the library are currently available at our web site for this project: http://fi.cvis.psy.utexas.edu. We have tested our real time software in conjunction with MPEG (H.263) and shown that it generally produces very substantial bandwidth savings both for I frames and P frames. We have also developed our own real time image compression library which includes fast motion compensation, fast pyramid coding, fast zero-tree coding and arithmetic coding. The foveated imaging software has been successfully interfaced and tested with a 512x512 8-bit b/w camera and two separate eye trackers: an ASL desktop heads-free eye tracker and the OWL/ASL V8 helmet mounted eye tracker.

14. SUBJECT TERMS			15. NUMBER OF PAGES
			16. PRICE CODE
17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
unclassified	unclassified	unclassified	SAR

A Foveated Imaging System to Reduce Transmission Bandwidth of Video Images from Remote Camera Systems

Final Technical Report

(prepared by W.S. Geisler)

AFOSR F49620-94-C-0090

Phase I: September 30, 1994 to March 31, 1995
Phase II: September 30, 1996 to September 30, 1998

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Introduction

This is the final progress report for a joint project between Geisler's laboratory at University of Texas at Austin and OWL Displays Inc., to develop a real time variable resolution (foveated) imaging system for video communications tasks such as remote control of unmanned vehicles.

The original objectives in Phase I were to develop fast and efficient software for encoding foveated images (to be done at UT), and to design and construct variable resolution display hardware for displaying the encoded foveated images (to be done at OWL). During Phase I a software encoder/decoder and a small test display were developed. However, the software was so efficient that conventional displays proved to be adequate for moderate sized images. Thus, in Phase II it was decided that OWL would focus only on developing a very high resolution display, while Geisler's lab would focus on improving the software encoder/decoder and on integrating it with a heads-free eye tracker. However, during Phase II a complete redesign of the software led to further increases in encoding/decoding speed and elimination of display artifacts that had existed in the earlier version on conventional displays. Thus, it became apparent by the second year of Phase II that the display technology that OWL could provide was not going to significantly enhance system performance. At that point OWL (with AFOSR approval) turned their attention to eye tracking technology to be used in conjunction with the foveated imaging software. OWL in cooperation with ASL Inc. succeeded in integrating a small eye tracker into a helmet mounted display (the Virtual Research Systems Inc. V8 helmet). This display system has been integrated and tested with the foveated imaging software. During the final year of Phase II financial difficulties overtook OWL; they filed for bankruptcy and are now out of business.

Although the OWL side of the project might best be described as a modest success, we believe the software and software/hardware integration performed at UT has been a big success.

Original Objectives

The specific original Phase I objectives were as follows:

1. Develop algorithms for foveated vision.
2. Implement and test algorithms on hardware platforms.
3. Interface camera, eye tracker and CRT hardware platform.
4. Develop a low cost monochrome screen for the foveated system based on OWL's technology
5. Develop lattice application specific integrated circuit (ASIC) interface.
6. Interface camera, eye tracker and OWL's display platform

7. Conduct a final comparison and assessment of achievable bandwidth reduction at given levels of display quality.

The specific original Phase II objectives were as follows:

1. Completion of a one-camera image acquisition system.

2. Reduction or elimination of the apparent motion effects seen in the Phase I FIS.

3. Construction of a higher resolution OWL display using a pulse driver.

4. Implementation of a heads-free eye tracking system (i.e. one that allows free head movements) and evaluation of its robustness.

5. Evaluation of human performance while using the system (for both conventional and OWL screen technologies), for a number of different image types and tasks, including visual search, text reading, and navigation through the environment.

6. Design and implementation of a data compression scheme to work in conjunction with the FIS to further reduce bandwidth requirements.

7. Evaluation of the Foveated Imaging System's transmission properties.

8. Evaluation of alternate hardware/software implementations.

Status of effort

Phase I Objectives 1, 2, 4 and 7 were completed. Objective 3 was completed except for interfacing of the camera which was accomplished during Phase II. Objectives 5 and 6 were not completed because of the change in OWL's objectives described in the Introduction. Phase II objectives 1, 2, 4, 6, 7 and 8 were all completed. Objective 3 was not completed because of another change in OWL's objectives described in the Introduction. Objective 5 was not completed in a rigorous fashion. Some behavioral testing, demonstrating the advantages of foveated imaging for optimizing search performance under fixed bandwidth transmission conditions, was completed in Phase I (Kortum & Geisler, 1996). However, for three reasons additional behavioral performance testing was not completed in Phase II. First, new insights led to a complete redesign of the software algorithms; these changes required considerable additional effort to implement. Second, the development of real-time conventional image compression algorithms appropriate for foveated imaging grew into a much larger effort than initially anticipated. Third, it was decided that higher priority should be placed upon demonstrating the compatibility of foveated imaging with existing image compression standards such as MPEG.

Work on the foveated imaging system and software libraries continues with some limited funding from UT. We plan to maintain and expand the software library for some years to maximize the chance for applications to develop.

Accomplishments/New Findings

The major accomplishments and findings are described here with an emphasis on work carried out at UT in Geisler's lab.

(1) A general purpose real-time C++ library has been developed for coding and decoding variable resolution static images and video, both in 8-bit gray scale and 24-bit color. This linkable library (for Pentium class computers running the Windows95/98/NT OS) will soon be made generally available for development and testing of applications involving variable resolution displays. We anticipate having the library available with documentation within a couple of months. Real-time demonstration executables using the library are currently available at our web site: http://fi.cvis.psy.utexas.edu.

The details of the algorithms are described in Geisler & Perry (1998) and in documentation available at the web site. In brief, a low-pass pyramid of 5-6 levels is first created. Each successive level of the pyramid is a copy of the image from the previous level, but at 1/2 the resolution in each direction (1/4 the number of pixels). Based upon the foveation points (i.e., the locations of highest resolution) subsets of pixels from each level of the pyramid are selected to create a series of smaller images. Typically, all of these smaller images together contain only a fraction of the total pixels in the original image. The subimages can then be processed in any fashion, just like normal images. For example, they can be MPEG coded and transmitted to a remote site and then MPEG decoded. The processed small images are then decoded, interpolated and smoothed by our software to obtained a displayable foveated image.

(2) We have tested our real time software in conjunction with MPEG (H.263) and shown that it generally produces very substantial bandwidth savings both for I frames and P frames. The results are described in documentation available at the web site. The results will appear in an invited SID paper (Geisler & Perry, 1999). As implied above, our foveation software was explicitly developed for pre- and post-processing, and hence it is generally compatible with a wide range of image processing hardware.

(3) We have also developed our own real time image compression software which includes fast motion estimation/compensation, fast pyramid coding, fast zero-tree coding and arithmetic coding. These are conventional state-of-the-art components of the best current image compression algorithms. Our contribution was to develop versions with very good real time performance. We have shown that our foveation coding increases the speed of subsequent processing because of the great reduction in the number of pixels that must be processed. With our software both variable resolution coding and more conventional image compression can be accomplished in real time for moderate sized images, without any special purpose hardware. A real-time C++ library of these routines will also be made generally

available for development and testing at or near the same time the foveated imaging library is made available.

(4) A foveated imaging web site has been created which contains much information about foveated imaging, including downloadable real-time demonstrations. This web site has received many hundreds of hits (from unique addresses) since its inception in September, 1998. Feedback about the demonstrations has been very positive. A number of laboratories have indicted that they plan to make use of the libraries as soon as they are available. On the basis of the web site and demonstrations, we will be giving an invited presentation on variable resolution displays at the Society for Information Display meeting in San Jose next summer. The downloadable demonstrations now include real-time foveation of static 8-bit color images and 24-bit color movies, where the user can control the foveation point with a mouse. In addition, there is a real-time simulation of fixed bandwidth telecommunications showing how foveation can dramatically increase frame rate without sacrificing field of view.

(5) We have interfaced the current foveated imaging software with a 512x512 8-bit b/w camera and two separate eye trackers: an ASL desktop heads-free eye tracker and the OWL/ASL V8 helmet mounted eye tracker. The software library contains appropriate routines for communicating with the ASL eye trackers. For most observers who have tried these eye-tracking systems the foveated imaging works quite well. However, we have found that for a small percentage of observers the eye trackers are not able to track over a wide range of gaze angles. We are planning a more systematic study of eye tracking with foveated imaging, however, we also believe that there are a number of applications where simpler pointing devices will be adequate.

(6) Two papers have been published on foveated imaging, one describing the Phase I work and one describing some of the Phase II work. A short paper will be published in the SID proceedings describing some of the most recent work.

(7) The University of Texas has filed for a patent on the foveated imaging algorithms.

(8) We have made progress in demonstrating the value of our variable resolution software in several applications including telecommunications, image retrieval and 3D simulation. For example, we are currently working on a video telecommunications test bed (with University equipment funds). Also, we have begun creating a demonstration of how foveated imaging can be used to speed 3D graphics simulation and rendering in the OpenGL environment.

Personnel Supported

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Publications

Kortum, P.T. and Geisler, W.S. (1996) Implementation of a foveated image-coding system for bandwidth reduction of video images. In B. Rogowitz and J. Allebach (Eds.) *Human Vision and Electronic Imaging. SPIE Proceedings*, 2657, 350-360.

Siegel, J. (1996) Coding of foveated images. Masters Thesis.

Geisler, W.S. and Perry, J.S. (1998) A real-time foveated multi-resolution system for low-bandwidth video communication In: B. Rogowitz and T. Pappas (Eds.), *Human Vision and Electronic Imaging, SPIE Proceedings* 3299, 294-305.

Geisler, W.S. and Perry, J.S. (1999) Variable resolution displays for visual communication and simulation. Society for Information Display (SID), San Jose, June 1999.

Geisler, W.S. and Perry, J.S. website: http://fi.cvis.psy.utexas.edu.

Inventions/patents

Foveated Image Coding System and Method for Image Bandwidth Reduction. Pat App. No. 08/997,109